Presentation Overview

- Principles of SPM: contact, tapping and phase modes
- A classification of SPM modes
  - Imaging modes
  - Spectroscopy modes
- Details of the MultiMode AFM
Generic SPM

- Sharp Probe
- Three Axis Scanner
- Detector of Probe-Sample Interactions
- Feedback Loop
- Isolation
Silicon Nitride cantilever
SPM Configurations

MultiMode
- Multi Purpose
- Scanned sample
- Highest resolution and most stable platform

Dimension 3100
- Multi Purpose
- Scanned Tip
- Small and Large samples

BioScope
- Scanned tip on Axiovert
- Life-sciences
- Fluid, in-vitro
Contact mode in fluid - example

Bacteriorhopsine molecules - cytoplasmic membrane face

15nm scan
D. Muller, Uni Basel
Contact mode in fluid

Contact Mode in Air

**Cantilever w/ tip**

**Fluid layer**

**Electrostatic charge**

Contact Mode in Fluid

**Fluid eliminates meniscus forces**

**Charge screened by ions**
Tapping mode AFM

- Scans probe on end of oscillating cantilever, in air and fluid

Fluid layer

10-100 nm

"Tapping"

"Free" Amplitude

Amplitude reduced

Veeco
Carbon nanotube on metal contacts tapping

Courtesy: C. Joachim, Toulouse
Force Curves example: ‘molecule pulling’

Pulling Mode: Titin IG27
Phase Imaging

Measured simultaneously during TappingMode imaging

The phase lag between cantilever oscillation and oscillation signal sent to the piezo driving the cantilever are monitored to map materials differences, such as adhesion and viscoelasticity.
Phase image highlights the two-component structure of composite regions (example: Poly(vinyl-cyclohexane) Block Copolymer)
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Imaging Applications

• **Topographical imaging**
  • Static imaging
  • Dynamic imaging (in-situ, EC environment, variable temperature,…)

• **Other Physical Properties**
  • Electrical:
    • EFM, Kelvin, SCM, TUNA, C-AFM, SSRM, 4PP
  • Magnetic
    • MFM
  • Mechanical
    • Friction, Torsion,
  • Other modes
    • Thermal, Optical
Imaging – static; large scan (65 μm)

- Contact mode image of endothelial cells
Imaging – static – high resolution (600 nm)

- TappingMode on normal alkalene $C_{60}H_{122}$ molecules on HOPG
Imaging – dynamic: DNA-Polymer Condensation (*In Situ*)

35 minute time-frame

800nm scans

TappingMode in Buffer Solution

Courtesy C. Roberts, Lab of Biophysics & Surface Analysis, Univ. of Nottingham, UK
Imaging – dynamic: PEO melting and recrystalization
Imaging Applications

- **Topographical imaging**
  - Static imaging
  - Dynamic imaging (in-situ, EC environment, variable temperature,...)

- **Other Physical Properties**
  - **Electrical**
    - STM, EFM, Kelvin, SCM, TUNA, C-AFM, SSRM, 4PP
  - **Magnetic**
    - MFM
  - **Mechanical**
    - Force Modulation, Force curves, Force Volume, Friction, Torsion
  - **Other modes**
    - Thermal, Optical
Magnetic Measurements: MFM

- Sample: carbon nanotubes, 5um scan

Isolated CNT
High concentration of CNT

LiftMode
lift 5-200 nm
Electrical Measurements 1: Electric Field Microscopy (EFM)

Sample: rubber-modified polypropylene filled with carbon black
Electrical Measurements 2: Kelvin

Topography

Surface potential

Scansize: 2x1 µm

Sample: nanowire on electrical contacts
Electrical Measurements 3: Scanning Capacitance Microscopy

Sample: Cross-sectioned Silicon bipolar transistors
Mechanical Measurements 1: Nano-Indentation in layered PE blend

Height image (left) & Profiles of indents in PE layers of different density
(sample was cross-sectioned by cryo-ultramicrotomy)
Mechanical Measurements 2: force modulation
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  • Spectroscopy modes (non-imaging modes)
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Spectroscopy 1: Force Curves ‘molecule

Example: Pulling Mode: Titin IG27, 5 pN force resolution
• Biotin-Avidin binding (~160 pN)
• Interactions between DNA (~1 nN)
• Unfolding of titin protein (~150-300 pN)
• Stretching DNA (~100’s pN)

![Diagram](image)
Spectroscopy 2: Force Volume

- Example: Layer of red blood cells from two different blood groups (A and O)
  - Tip with an antibody specific to type A blood cells

Spectroscopy 3: I-V curve on selected spot

Topography & current images

I-V curve at selected location
Lithography by scripting & file import

Antidot lattice on AlGaAs/GaAs
(courtesy A. Dorn & A. Fuhrer,
ETH Zurich, CH)

Dog on Si
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MultiMode AFM
MultiMode specifications

- **Scanners:**
  - 120x120x6 um … 0.4x0.4x0.4um
  - automated engagement (vertical)

- **Resolution**
  - atomic
  - <0.03nm RMS noise

- **Modes:**
  - **Standard imaging:** contact, tapping, STM, LFM, phase
  - **forces:** force curves, force volume, indentation
  - **Electrical/magnetic:** EFM, MFM, lithography
  - **Optional:** SCM, SSRM, C-AFM, TUNA, SThM...
MultiMode scan head

- Scan head:
  - fixed tip
  - low noise laser diode
  - 15 mm Ø samples
Liquid cell

False reflection from glass (faint)

Reflection from cantilever (bright)

Laser beam

Fluid tipholder (glass)

O-ring

Sample

Sample puck

Scanner

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Application modules for electrical measurements

- Scanning Capacitance
- Scanning Spreading Resistance
- Tunneling AFM
- Conductive AFM *
- Scanning Thermal
- ...

*Veeco*
Atmospheric Hood for Environmental Controls

- Allows purging of the MultiMode environment at or slightly above atmospheric pressures with gases such as O2, N2, He, Air, or other inert, non-toxic gases while scanning.
- Strongly recommended for users who need environmental control for applications including polymer analysis and advanced investigation of biological specimens.
Heater / Cooler Hardware

Gas Tight Cell

Integrated Heater

Silicone Sleeve